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14. ABSTRACT

The aim of this project is to develop a new approach and its theoretical and experimental framework, to automatically and rapidly quantify invisible defects in a composite structure through enhanced analysis of data from ultrasonic non-destructive inspection methods.

15. SUBJECT TERMS

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Annual Report

Title: Cooperative Belief-Driven Search and Tracking

AFOSR/AOARD Reference Number: AOARD-08-4129

AFOSR/AOARD COTR: Lt Col John Seo
Program Manager: Lt Col Eric Stierna, ITC-PAC

Period of Performance: Oct 2008 – Sep 2009

Submission Date: 29 Dec 2009

PI: Prof Tomonari Furukawa, Virginia Polytechnic Institute and State University

PROJECT OUTLINE

Aims

The aim of this project is to develop a new approach and its theoretical and experimental framework, to automatically and rapidly quantify invisible defects in a composite structure through enhanced analysis of data from ultrasonic non-destructive inspection methods.

Technical Milestones

Technically, the project is aimed at developing rapid automated techniques that:

Interrogate output from ultrasonic NDI equipment to identify the presence of defects in composite structures. The complexity of composite materials and structures make return signals also complex and thus difficult to interpret. The proposed enhanced signal analysis attempts to identify the presence by modeling signals and geometries more accurately than any existing technique.

Identify the type of defect, in particular delamination, disbonding, foreign body inclusions and porosity. The incorporation of information-theoretic approaches will not only identify the presence but also the type.

Characterize the damage with respect to its location and size. The proposed enhanced signal analysis is recursively performed by utilizing active sensing. This will allow the damage to be characterized in terms of not only location but also size. Future discussion on the NDI, such as coordinated sensing, can also start by developing fundamentals through this research project.

Review of Related Work

The most commonly used NDI techniques for composite structures are based on the transmission and reflection of ultrasonic waves in composite structures. The patterns of such reflected and transmitted signals are used to detect anomalies in the structure indicating defects. Many such systems are commercially available and are widely used in manufacturing for production quality control and in maintenance of structures to detect defects due to operational factors. The calibration of such systems and the interpretation of the results to detect and characterize defects rely on skilled and experienced operators. The thorough inspection and evaluation of large structures is labor intensive and involves long elapse times.

Significance and Scientific Impact

The outcome of this research will benefit both the manufacture and maintenance of composite structures, particularly for aerospace applications. The achievement of the above objectives will lead to more cost effective and more reliable NDE and in particular will lead to a greatly reduced elapse time for testing of large structures and consequently reduce aircraft down-time. As the US military moves towards greater utilization of composite aircraft structures, the implementations of such systems will lead to substantial cost savings and to greater utilization of high value assets.

SCHEDULE

The proposed approach will enhance images acquired experimentally by modeling wave propagation in composite materials and incorporating finite element analysis (FEA). To maximize the reliability of defect identification, which contains various uncertainties due to imperfections of composite materials, irregularities of their structures, inaccuracies of the sensor

measurement and environmental factors, the proposed approach will further adopt stochastic estimation by modeling any available information and processing it information-theoretically. The project will finally explore a technique for active sensing such that the defect identification can be carried out efficiently over the surface of a large structure.

The technical breakdown of the project is as follows:
1. Modeling wave propagation in composite materials [**Month 6**];
2. Developing FEA capabilities for wave propagation in composite structures [**Month 9**];
3. Developing a technique that enhances current signal analyses to rapidly, automatically and accurately visualize defects [**Month 12**];
4. Develop automated techniques to characterize defects [**Month 16**];
5. Developing a technique that stochastically estimates the states of defects at every acquisition of reflected waves [**Month 20**]; and
6. Developing a technique that allows active sensing to optimally position sensors which enhance rapid field inspection [**Month 24**].

SCHEDULE

In order to enhance research, the PI will participate in US Army's ITC-PAC organized MAGIC 2010 event. The final report will be submitted after this event. This future of this research will be funded by ITC-PAC for the second year. [Filed by Lt Col John Seo, 29 Dec 2009.]